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Implied risk premium in the soybean future contracts

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Dissertação submetida ao Programa de Pós-Graduação em Economia da Faculdade de de Ciências Econômicas da UFRGS, como quesito parcial para obtenção do título de Mestre em Economia, com ênfase em Economia Aplicada.

Orientador: João Frois Caldeira

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Ao meu pai, Carlos Samanez.
In memoriam.

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“But as for you, be strong and do not give up,
for your work will be rewarded.
(II Crônicas, 15:7)

Resumo

Neste artigo, avaliamos o prêmio de risco implícito incorporado nos preços futuros de soja através de um modelo de dois fatore bem conhecido na literatura de commodities. Como os preços da soja na última década têm flutuado muito, primeiro examinamos as quebras estruturais na variância/volatilidade para obter uma proxy para as mudanças nos prêmios de risco. Em seguida, calibramos o modelo de dois fatores em cada subperíodo de toda a série de acordo com as quebras encontradas. Em seqüência, calculamos o prêmio de risco implícito pelo modelo. Constatamos que o prêmio de risco é variável no tempo, não apenas no sinal, mas também na magnitude. Além disso, quando os preços estavam subindo, a posição dominante era dos produtores protegendo-se com um prêmio de risco positivo, enquanto quando os preços estavam caíndo, consumidores se protegiam com um prémio de risco negativo.

Palavras-chave: Prêmio de risco. Contratos futuros agrícolas. Modelos em commodities.

Abstract

In this paper we evaluate the implied risk premium embedded in soybean future prices through a well-known two-factor model in the commodity literature. Since soybean prices in the past decade have fluctuated greatly, we first examine the structural breaks in variance/volatility to obtain a proxy for risk premiums changes. Then we calibrate the two-factor model in each sub-period of the entire series according to the breaks found. In sequence we compute the risk premium implied by the model. We find that the risk premium is time-varying, not only in sign but also in magnitude. Furthermore, when prices were rising prevailing position was of producers hedging with a positive risk premium, while when prices were falling consumers hedged with a negative risk premium.

Key-words: Risk premium. Agricultural futures contracts. Commodity models.

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1 Introduction

An important fact that distinguishes commodities from other financial assets (such stocks, bonds and, exchange rates) is the presence of high volatility. The main component that influences these price variations is the seasonal effect. Agricultural commodities are particularly influenced by weather conditions. On the other hand, agricultural commodities are perishable goods, making them more volatile and costly to store. The importance of analysing agricultural commodities is mainly related to food price inflation. Episodes of agricultural price spikes are important for their potential negative impacts on food security.

The same can be said regarding agents perceptions of the risk involved in trading agricultural commodities. The risk of price spikes in trading agricultural commodities is related to geopolitical and weather uncertainties and also to government decisions. Furthermore, rising food prices tend to affect lower income consumers more, because they have a larger share of their budgets allocated to food. Corn, wheat, rice and soybean account for a large share of the agricultural commodities consumed globally. Specifically, soybean provides oil and other products for human consumption and protein for animals.

The main goal of this paper is to extract the risk premium information embedded in future soybeans prices. The risk premium contains relevant information on agents risk perception of the future spot price matching the future price. Also, the risk premium gives a notion of risk transfer between hedgers and speculators.

In the finance literature, the general procedure for this purpose is the use of regression analysis. However this is not a simple task, mainly for agricultural commodities. Frank and Garcia (2009) highlight the difficulties involved in this approach. In this paper we follow a different route. We evaluate the implied risk premium captured through the well-known commodity model of Schwartz and Smith (2000).

Historically soybean prices fluctuated around US$ 615 cents/bushel in the period between 1973 and 2006. After 2006, prices rose rapidly reaching US$ 1,648 cents/bushel by July 2008 (see Figure 4). This surge in soybean prices was a common feature in the prices of many commodities in the first decade of the century. For most food crops, the main contributor to this steep rise was the rising demand from developing economies in this period.

Biofuel production also increased as a consequence of high energy prices. This increased demand for biofuels shifted the land use and boosted agricultural commodity prices. This effect was different among crops. A common factor that affected all commodity prices was the depreciation of the U.S. dollar. Also, the speculation in commodity markets played a significant role; see Hochman et al. (2014) and the references therein.

In the second half of 2008, commodity prices followed the general behavior of financial assets, dropping abruptly due to the subprime crisis and fears of economic recession. Nevertheless, soybean prices did not return to the pre-2006 levels. They continued to spike in 2010-2011. By September 2012, prices reached US$ 1,771.18 cents/bushel. Thereafter, prices started a period of decline due to a significant slowdown in China's growth rate. In the second half of 2014, soybean prices plunged and in 2016 prices ranged between US$ 980 cents/bushel and US$ 1,000 cents/bushel. This recent scenario is related to a decline in overall economic activity. Nonetheless, soybean prices have never returned to the levels before 2006.

Aiming to evaluate the risk premium during this recent time series, and since prices have changed dramatically, we decided to map changes or structural breaks in volatility. Changes in volatility are clear indicators of changes in investors' risk perceptions. Therefore, this mapping can provide insights into the changes in the risk premiums. To do this, we started by using the ICSS (Iterated Cumulative Sum-of-Squares) algorithm of Inclan and Tiao (1994). Once changes in risk perceptions were mapped, we calibrate the Schwartz and Smith (2000) model and computed the implied risk premium.

The paper is organized as follows. Section 2 explains the basic risk premium concepts and provides an overview of the literature. Section 3 presents the methodology. Section 4 details the data and presents the main results.

2 Basic concepts of risk premium

The main reason for the existence of future markets is to allow agents to hedge their positions. Agents use the futures markets to transfer the price risk to speculators. On the other hand, speculators need to be rewarded to bear this risk. Their compensation is defined as the risk premium and is embedded in the price negotiated. Furthermore, futures markets are used as a predictor of the future spot price. An important issue in the finance literature is to extract the risk premium embedded in future prices data. So, the existence of a risk premium is explained as a risk transfer mechanism between market agents and focus on the role of hedging.

The theory of storage, argues that the difference between the current spot and futures price can be explained by interest rates, storage costs (buying and holding the physical commodity), and a convenience yield (defined as the benefit inherent to the owner of the physical commodity which can be seen as dividends payed in the case of financial assets). This approach states that convenience yields depends on inventories levels, so the level of the inventory is connected to the future spot price. The value of inventories arise as they absorb demand and supply shocks (can be used to meet unexpected fluctuations on demand), therefore a risk of exhaustion in inventories increases the expected future spot prices and volatility rises. Therefore, if storage levels are low, value of inventories are high, implying high convenience yields. Convenience yield models were first discussed in Working (1949) and Kaldor (1939) and theory of storage implications in Brennan (1958), Telser (1958) and Working (1949).

A common theory used to explain commodity futures prices states that future price equals the sum of the expected spot price at maturity of the future's contract and a risk premium, this risk premium models were originated by Keynes (1930) and Hicks (1939). Following this idea, consider a future contract to deliver a unit of the commodity on a future date T (contract maturity). Define the price of this contract at t as $F_{t,T}$, the risk premium as $RP_{t,T}$, and, following the literature, the risk premium as

$$RP_{t,T} = E^P\left(S_T|\mathcal{F}_t\right) - F_{t,T} \tag{2.1}$$

where S_T is the spot price at the maturity of the contract, $E^P\left(\cdot|\mathcal{F}_t\right)$ is the expectation operator under the physical measure P and $\mathcal{F}_t$ represents the information available up to time t.

Keynes (1930) was the first economist to formalize the theory of risk premiums, inventory, and the shape of the futures curve (term structure of futures prices). When the risk premium is positive in equation (2.1) ($F_{t,T} < E^P\left(S_T|\mathcal{F}_t\right)$), the term structure of future prices is in normal backwardation. Speculators long position would be lucrative as future prices will increase, converging to the spot price at $t = T$. The opposite situation ($F_{t,T} > E^P(S_T|\mathcal{F}_t)$), where the risk premium is negative, it is called contango.

Consider commodity producers interested in hedging their physical position (inventories or production). To do so, they enter into a short position in a future contract that matches their delivery date. This is a way to be protected against a lower spot price. Commodity consumers may be interested to insure against increases in the spot prices as speculators are expecting an increase in future prices, therefore they enter into a long position. This means that at time t the risk premium is positive.

Secondly, consider commodity consumers who want to hedge their position. They go long in a future contract to insure against increases in the spot price. Producers and speculators (bearing the consumer risk) are expecting a decrease in future prices as maturity approaches, so they go short. This means that at time t the risk premium is negative. The sign of risk premium is defined by agents' expectations regarding what is going to happen until the maturity T. It is reasonable to imagine that the risk premium is time-varying since agents' expectations vary according to the news that affects the markets at each moment.

The analysis of time varying risk premiums in the commodity literature is conducted empirically and goes back to Cootner (1960). Consider $F_{t,t+1}$ a future price at time t maturing at $t+1$ and S_t the spot price. Market efficiency and unbiasedeness of future price are given by the same equation written as $F_{t,t+1} = E^P(S_{t+1}|\mathcal{F}_t)$. Assuming rational expectations, one can write $S_{t+1} = E^P(S_{t+1}|\mathcal{F}_t) + \epsilon_{t+1}$, where ϵ_t is white noise. Therefore, one ends up with

$$F_{t,t+1} = S_{t+1} + \epsilon_{t+1} \tag{2.2}$$

This approach tests the predictive content of futures prices: if the risk premium is zero, futures prices are good predictors of spot prices.The details on the empirical analysis of risk premiums can be seen in Moosa and Al-Loughani (1994).

There are many studies in this respect. Fama and French (1987) conducted an analysis investigating different agricultural and metal commodities. They found evidence of the forecast power of futures prices and a time-varying risk premium for many of them. Alquist, Bauer and Rios (2013) find that oil futures are not good predictors of subsequent oil prices in contrast to Chinn and Coibion (2014), they suggest that futures are good predictors of spot prices in some periods but not all the time.

Energy commodities are also considered in this type of analysis. Chong and Miffre (2006) investigated the risk premium and correlations in commodity futures markets. They used agricultural, livestock and metal commodities. First they tested the presence of risk premium. Second, they analysed the correlation between futures and S&P500 and also the US treasury bonds index. The data covered prices from 1979 to

2004.

Geman and Ohana (2009) expanded the Fama and French's study by investigating the oil and the U.S. natural gas futures markets. Huisman and Kilic (2012) studied the European electricity markets, comparing the risk premiums from storable-based fuels and hydropower. Hamilton and Wu (2014) investigated the risk premiums in crude oil futures prices motivated by the recent presence of financial funds in commodity markets, as mentioned before, a phenomenon called commodity financialization.

The closest work to this study is that of Aiube and Samanez (2014). They analysed the term structure of prices, risk premium and volatility in the oil futures prices traded on NYMEX using the Schwartz and Smith (2000) two-factor model and three-factor model. Here we found structural breaks in volatility using the ICSS algorithm on weekly data. Furthermore, as examples of the use of factor models in agricultural commodities, we can mention Geman and Nguyen (2005) and Sørensen (2002). In the former paper, the authors investigated the soybean inventories and the term structure of forward curves through two- and three-factor models. In the last paper, the author investigated the seasonality of agricultural futures contracts using the Schwartz and Smith two-factor model.

3 The methodology

3.1 Structural breaks

According to many studies mentioned above, there is empirical evidence that the risk premiums are time-varying. To study variations of the risk premium (involved in futures markets of a certain asset) we need to evaluate the risk perceptions of agents through the positions in futures contracts. For this purpose we investigate the structural breaks in variance of the first future contract (which is the most liquid and is a better proxy for the spot price). Changes in variance have important implications for understanding the hedging positions involved in derivatives, such as options and futures contracts.

The analysis of a structural break in financial time series is widespread in the econometric literature. A survey of this subject can be found in Andreou and Ghysels (2009). The methodology used to map the sudden changes in variance is based on the iterated cumulative sums-of-squares (ICSS) algorithm of Inclan and Tiao (1994). We test the null hypothesis of a constant unconditional variance of the returns in the first contract against the alternative of structural breaks in the unconditional variance.

Let $\{\epsilon_t^2\}$ denote a time series of independents observations with normal distribution, zero mean and unconditional variance σ_t^2 . The variance between each range of changes is σ_i^2 for $i = 0, 1, 2, \cdots, m$, where m is the total number of structural changes in the variance in N observations. Thus, the unconditional variance σ_t^2 changes for each interval between sudden changes in variance.

$$\sigma_t^2 \begin{cases} \tau_0^2, & 1 < t < t_1 \\ \tau_1^2, & t_1 < t < t_2 \\ & \vdots \\ \tau_m^2, & t_m < t < t_T \end{cases} \tag{3.1}$$

To test the null hypothesis of constant unconditional variance, the Inclan-Tiao test statistic is given by:

$$ICSS = \sup_k \left| N^{-0.5} \hat{\gamma}^{-0.5} \left(C_k - \frac{k}{N} C_N \right) \right| \tag{3.2}$$

where $C_k = \sum_{t=1}^{k} \epsilon_t$, for $k = 1, \ldots, N$, $\hat{\gamma} = \hat{\delta}_0 + 2 \sum_{t=1}^{m} \left[1 - i\,(m+1)^{-1} \right] \hat{\delta}_t$, $\hat{\sigma}^2 = N^{-1} C_N$, and $\hat{\delta}_k = N^{-1} \sum_{t=1}^{k} (\epsilon_t^2 - \hat{\sigma}^2) \left(\epsilon_{t-1}^2 - \hat{\sigma}^2 \right)$. To find the truncation parameter m the Newey and West (1994) procedure is used.

The estimation date of a break in variance is defined as the k value that maximizes equation (3.2). Under the assumption of normality of ϵ_t, the asymptotic distribution of the ICSS statistic is given by $\sup_c |W^\star(c)|$, where $W^\star(c) = W(c) - cW(1)$ is a Brownian bridge process, $0 \leq c \leq 1$, and $W(c)$ is the standard Brownian process. There are many studies in the literature using the ICSS algorithm, among them Malik (2003), Wilson, Aggarwal and Inclan (1996), Aggarwal, Inclan and Leal (1999) and, Arouri et al. (2012).

3.2 Schwartz and Smith's two-factor model

The literature on commodity markets using stochastic processes is huge. The general procedure is to estimate spot prices from the term structure of futures prices using a filtering method. In the Gaussian environment, the Kalman filter is used for this purpose. Since the publication of the two-factor model of Schwartz and Smith (2000), many other studies have used it directly or made some extensions. In the following we mention a few of them.

Manoliu and Tompaidis (2002) used this model to analyze natural gas prices in the U.S. market. Sørensen (2002) studied seasonality in agricultural commodities. Lucia and Schwartz (2002) and Villaplana (2004) analyzed electricity markets. Aiube, Baidya and Tito (2008) extended the Schwartz and Smith model by introducing the jump component in the dynamics of the short-term factor hence making it no longer Gaussian. They performed the empirical estimation using the particle filter method.

Consider a futures markets having M future contracts maturing at $T_j,\ j = 1, \ldots, M$. The price of the contract j traded at t and maturing at T_j is denoted by F_{t,T_j}. The economy is arbitrage-free and Q is the EMM (equivalent martingale measure) of the real measure P. The spot price of such a commodity at t is S_t and it will be estimated from the future prices (observed variables).

The spot price is decomposed into two latent factors: χ_t and ξ_t. The first factor follows an Ornstein-Uhlenbeck process reverting to zero with speed of reversion κ and volatility σ_χ. It is called the short-term variations and is a concept related to the convenience yield in the Gibson and Schwartz (1990) model, in other words, represents transitory shocks that reverts to zero mean, like the effects of temporary variations in stocks, demand and climatic variations. The second factor ξ_t evolves according to geometric Brownian motion with drift μ_ξ and volatility σ_ξ. It is called the long-term equilibrium price. It models the long-run price, which reflects changes in production technologies, regulatory conditions arising from environmental problems, structural changes in production costs and any issue that reflect the commodity supply. The uncertainty is driven by two standard Brownian processes, B_{χ_t} and B_{ξ_t}, which are correlated as $dB_\chi dB_\xi = \rho dt$. The model in the P-measure is written as

$$ln(S_t) = (f\,(t) + \chi_t + \xi_t) \quad (3.3a)$$

$$d\chi_t = -\kappa\chi_t dt + \sigma_\chi dB_{\chi t} \quad (3.3b)$$

$$d\xi_t = \mu_\xi dt + \sigma_\xi dB_{\xi_t} \quad (3.3c)$$

where the function $f\,(t)$ is deterministic function that describes the seasonal effects on commodity prices, $\kappa > 0$, $\sigma_\chi > 0$, $\sigma_\xi > 0$ and the pair (χ_0, ξ_0) is unknown.

As in Schwartz and Smith (2000), the future prices F_{t,T_j} for $j = 1, \ldots, M$ are observable and the state factors χ_t and ξ_t are unobservable, thus the spot price S_t is also unobservable, meaning that the spot prices should be estimated through filtering of the observable future prices. For commodities, the idea that the spot price is not observable is generally accepted. Therefore, a set of future contracts can be used to calibrate the model, taking into account the risk neutral measure. Formally, $F_{t,T} = E^{\mathbb{Q}}\left[S_T\,|S_t\right]$ under Q-EMM, where $F_{t,T}$ is the future contract at t with maturity at T ($0 \leq t \leq T$). In order to correctly price commodities future contracts, we use the risk neutral version of Schwartz and Smith (2000), adding two constant parameters, viewed as the risk premium for each of the uncertainty factors λ_χ and λ_ξ. Now, the risk neutral process associated with the short-term variation (χ_t) is an Ornstein-Uhlenback process reverting to mean $-\lambda_x/\kappa$ and the risk neutral process for the long term equilibrium (ξ_t) is a geometric Brownian motion with drift $\mu_\xi^\star$.

Under the Q-EMM the model is written as,

$$d\chi_t = (-\kappa\chi_t - \lambda_\chi)\,dt + \sigma_\chi d\tilde{B}_{\chi_t} \quad (3.4a)$$

$$d\xi_t = (\mu_\xi - \lambda_\xi)\,dt + \sigma_\xi d\tilde{B}_{\xi_t} \quad (3.4b)$$

where λ_χ, λ_ξ are the market prices of risk for both factors, $d\tilde{B}_{\chi_t} d\tilde{B}_{\xi_t} = \rho dt$, and we use the definition $\mu_\xi - \lambda_\xi = \mu_\xi^\star$.

It can be proven [1] that

(a) The logarithm of the spot price ($ln(S_t)$ has normal distribution with parameters showed in equations (3.5) and (3.6)

$$E^{\mathbb{Q}}\left[\ln\left(S_{T_j}\,|S_t\right)\right] = f(T_j) + e^{-\kappa(T_j - t)}\chi_t - \frac{\lambda_\chi}{\kappa}(1 - e^{-\kappa(T_j - t)}) + \xi_t + (\mu_\xi - \lambda_\xi)(T_j - t) \quad (3.5)$$

[1] The general details of this model can be seen in Schwartz and Smith (2000), Manoliu and Tompaidis (2002), Aiube and Samanez (2014), among others.

$$V^{\mathbb{Q}}\left[\ln\left(S_{T_j}\left|S_t\right.\right)\right] = (1 - e^{-2\kappa(T_j - t)})\frac{\sigma_\chi^2}{2\kappa} + \sigma_\xi^2(T_j - t) + 2(1 - e^{-2\kappa(T_j - t)})\frac{\sigma_\chi\sigma_\xi\rho}{\kappa} \tag{3.6}$$

(b) The term-structure of futures prices, which is the price at t for a contract maturing at T_j, is

$$\begin{aligned} \ln\left(F_{t,T_j}\right) &= E^{\mathbb{Q}}\left[\ln\left(S_T\left|S_t\right.\right)\right] + \tfrac{1}{2}V^{\mathbb{Q}}\left[\ln\left(S_T\left|S_t\right.\right)\right] \\ \ln\left(F_{t,T_j}\right) &= f\left(T_j\right) + \exp\left(-\kappa\left(T_j - t\right)\right)\chi_t + \xi_t + A\left(T_j - t\right) \qquad j = 1, \ldots, m, \end{aligned} \tag{3.7}$$

where

$$A\left(T_j - t\right) = \mu_\xi^\star\left(T_j - t\right) - \left(1 - \exp\left(-\kappa\left(T_j - t\right)\right)\right)\frac{\lambda_\chi}{\kappa} +$$

$$\frac{1}{2}\left[\left(1 - \exp\left(-2\kappa\left(T_j - t\right)\right)\right)\frac{\sigma_\chi^2}{2\kappa} + \sigma_\xi^2\left(T_j - t\right) + 2\left(1 - \exp\left(-\kappa\left(T_j - t\right)\right)\right)\frac{\rho\sigma_\chi\sigma_\xi}{\kappa}\right].$$

(c) Finally, we can calculate the term-structure of risk premium

$$\begin{aligned} RP_{t,T_j} &= E[S_{T_j}] - E^Q[S_{T_j}|S_t] \\ RP_{t,T_j} &= exp(f(T_j) + e^{-\kappa(T_j - t)}\chi_t + \xi_t + R(T_j - t)) \\ &\quad - exp(e^{-\kappa(T_j - t)}\chi_t + \xi_t + A(T_j - t)) \qquad j = 1, \ldots, m, \end{aligned} \tag{3.8}$$

where

$$R(T_j - t) = \mu_\xi(T_j - t) + \frac{1}{2}\left((1 - e^{-2\kappa(T_j - t)})\frac{\sigma_\chi^2}{2\kappa} + \sigma_\xi^2(T_j - t) + 2(1 - e^{-\kappa(T_j - t)})\frac{\sigma_\chi\sigma_\xi\rho}{\kappa}\right)$$

The hyperparameters of the model are defined according the vector Θ which is Θ = $\left(\kappa, \sigma_\chi, \mu_\xi, \sigma_\xi, \rho, \lambda_\chi, \mu_\xi^\star, s_j, \theta\right)$, where s_j is the standard deviation of the difference between observed and modeled futures prices of the j-th contract and θ is a vector containing the parameters of the seasonal component (described next). The Kalman filter allows estimating the latent variables and the hyperparameters are estimated by maximizing the likelihood of the prediction error.

In the Schwartz and Smith (2000) model, χ_t and ξ_t have normal distribution. Furthermore, equation (3.7) admits gaussian noise to the observable variable F_{t,T_j} and we can see that the logarithm of the future prices is linear in both state variables, in other words, the model is linear and gaussian. Thus, the Kalman filter is the appropriate methodology to address this problem by writing it in the state-space form.

4 Results

We sampled historical futures prices from the Chicago Board of Trade (CBOT) encompassing the period January 3, 2005 to May 6, 2016. The sample is a panel with weekly prices containing the most liquid contracts traded: 2, 4, 6, 8, and 10- months-ahead. We denote by F_j the j-th future contract. The series were rolled over close to the maturity to avoid the natural turbulence in this period. Prices are in US$ cents per bushel. Table 1 presents the main statistics for the entire sample.

Table 1 – Main statistics of prices in the first period: January 3, 2005-May 6, 2016

	F_1	F_2	F_3	F_4	F_5
Mean	1063.65	1058.78	1052.60	1044.57	1036.94
Maximum	1771.00	1768.25	1766.25	1712.00	1644.75
Minimum	499.50	502.25	507.00	510.25	512.25
Std. dev.	308.45	298.74	287.99	276.51	266.39
Skewness	-0.039	-0.038	-0.048	-0.078	-0.11
Kurtosis	-1.027	-1.014	-0.970	-0.959	-0.96

Source: Prepared by the author (2017)

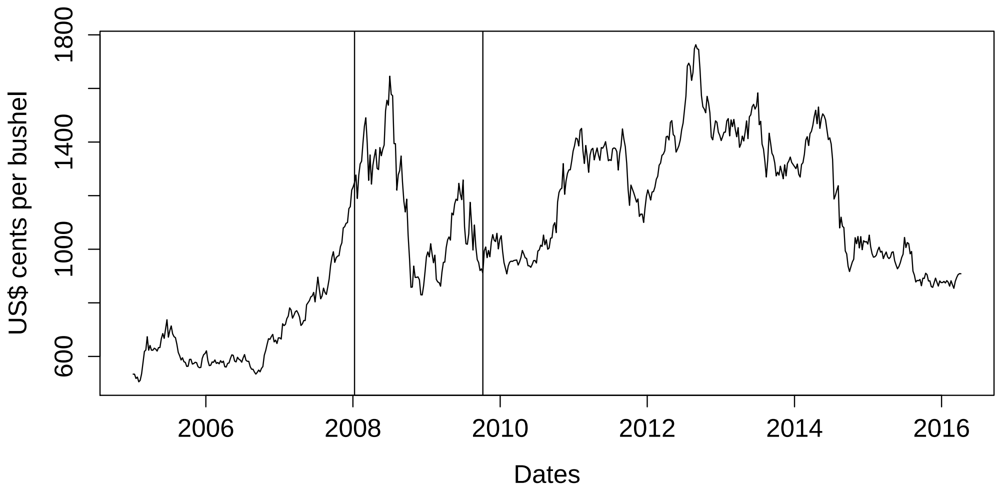
We use the F_1 contract (since this is the most liquid among all five series sampled) to run the ICSS algorithm and map the structural breaks in unconditional variance. We find two change points in the volatility regime: January 9, 2008 and October 7, 2009. Hence, there are three periods in which the variance/volatility changed in the entire sample. Figure 4 exhibits the prices for the F_1 contract, where the vertical lines indicate the breaks found in the volatility. Figure 2 shows the returns series. Note on the second period that the series is more noisy.

Seasonal influences can be modelled as deterministic or stochastic patterns that repeat once every year. Researchers often use dummy variables to model seasonality, imposing that the sum of the seasonal components is zero. Alternatively, we can model seasonality in terms of trigonometric functions as in Hannan (1964) or Hevia, Petrella and Sola (2016). We decided to use a combination of trigonometric functions based in Sørensen (2002). The function $f(t)$ in equation (3.3a) is

$$f(t) = \alpha_1 cos\left[2\pi\left(t + \beta_1\right)\right] + \alpha_2 cos\left[4\pi\left(t + \beta_2\right)\right]. \tag{4.1}$$

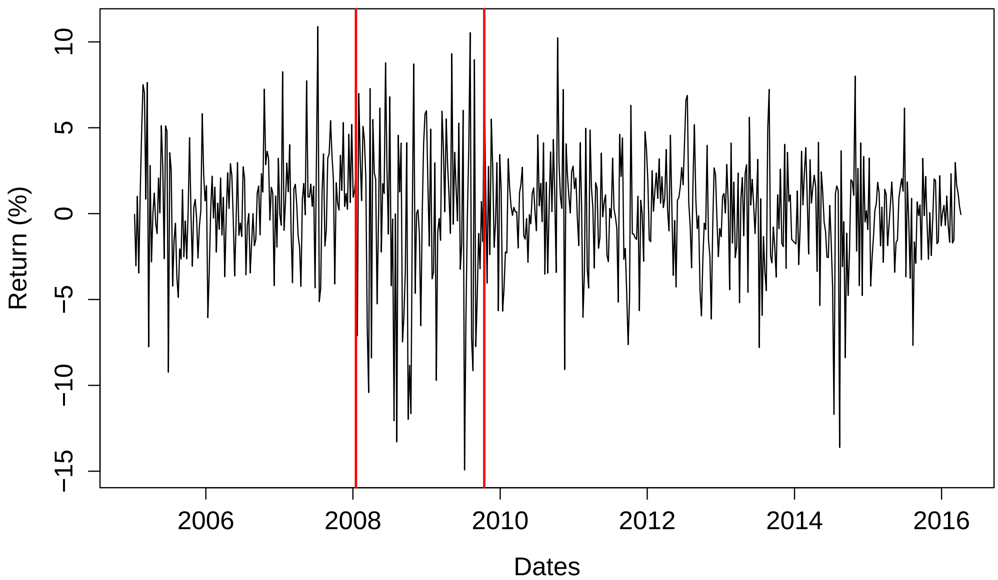
Defining $\theta = (\alpha_1, \beta_1, \alpha_2, \beta_2)$ where α's are the magnitude and β's are the phase, factors that integrate the seasonal effects. As seen in section 3, θ is a component of vector Θ.

Figure 1 – Soybean prices for first contract with volatility breaks in the vertical lines



Source: Prepared by the author (2017)

Figure 2 – Soybean returns for first contract



Source: Prepared by the author (2017)

Next, we calibrate the three periods estimating the hyperparameters of the model through the MLE (maximum likelihood estimator), and the unobservable variables (χ_t and ξ_t) through the Kalman filter, to estimate the spot price S_t. The estimation results are presented in Table 2.

From the results in Table 2, one can observe that the short-term market price of risk (λ_χ) is not significant in the second and third periods. Further, the drifts (μ_ξ) in the

Table 2 – Calibration results for the three periods

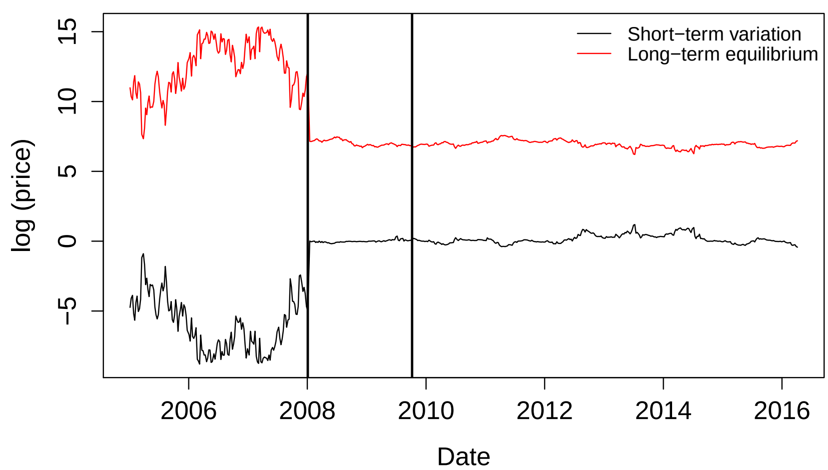
Parameter	first period MLE value	first period Std error	second period MLE value	second period Std error	third period MLE value	third period Std error
κ	0.031^{***}	0.0043	4.152^{***}	0.4833	0.6477^{***}	0.194
σ_χ	6.548^{***}	0.7679	0.410^{***}	0.0498	0.6420^{***}	0.158
μ_ξ	0.583^{***}	0.1385	-0.186	0.2928	0.0683	0.093
σ_ξ	6.462^{***}	0.7628	0.401^{***}	0.0327	0.0683^{***}	0.149
ρ	-0.999^{***}	0.0001	-0.265^{**}	0.1288	-0.9305^{***}	0.039
λ_χ	-12.023^{***}	1.6608	0.006	0.1691	-0.0990	0.102
$\mu_\xi^\star$	-11.556^{***}	1.7058	-0.155^{***}	0.0225	-0.1369^{**}	0.069
α_1	0.0113^{***}	0.0011	-0.041^{***}	0.0025	0.0292^{***}	0.002
β_1	-0.2071^{***}	0.0146	0.200^{***}	0.0106	0.7398^{***}	0.010
α_2	-0.0035^{***}	0.0003	0.009^{***}	0.0009	0.0071^{***}	0.001
β_2	0.8647^{***}	0.0081	0.058^{***}	0.0080	0.5776^{***}	0.006

Note: asterisks **, *** denote 5% and 1% significance level, respectively.

Source: Prepared by the author (2017)

second and third periods are not significant. However, this last result is not a surprise since it is well known that drift is the most difficult parameter to estimate. Its estimation depends on longer time series. All other parameters are significant. Note that the latent variables have a high negative correlation. This is a common situation when prices have a steep ramp up, for the following reason: as prices increase, the ξ variable (long-term) also increases and, as χ variable reverts to zero, it tends to move down. This is more prominent in the first and third periods when prices had a prevalent upward movement. Figure 3 shows the evolution of the latent variables.

Figure 3 – Long-term equilibrium and short-term variations evolution



Source: Prepared by the author (2017)

The downward movement in the last portion of the data series collected was not sufficiently long to define another period. We do not show the standard error for each measurement equation of future prices (the s_j parameter in the Θ vector). All of this omitted information is available on request.

After the model calibration for all three periods, we use equation (3.8) to compute the implied risk premium RP_{t,T_j} so we can build the risk premium term structure for all maturities. Table 3 presents the results for all periods, including some main statistics. The mean of the risk premium in the first period is positive and increases with the maturity of the contract. As explained in section 2, the market is in normal backwardation. That is the case when producers are looking to hedge their exposures going into a short position and speculators, expecting an increase in future prices, need prices lower than the ones observed in the spot market. In the first period, when soybean prices were increasing the interest of producers prevailed, paying a required premium so speculators could bear the risk.

Table 3 – Implied risk premium (US$ cents/bushel)

	F_1	F_2	F_3	F_4	F_5
			First Period		
Mean	4.398	14.512	28.088	45.613	67.539
Std. dev.	2.740	4.901	7.951	12.032	17.087
			Second Period		
Mean	-1.369	-3.964	-6.663	-9.411	-12.102
Std. dev.	0.810	1.101	1.515	2.018	2.559
			Third Period		
Mean	6.261	17.903	29.954	42.367	55.114
Std. dev.	3.603	4.803	6.363	8.048	9.827

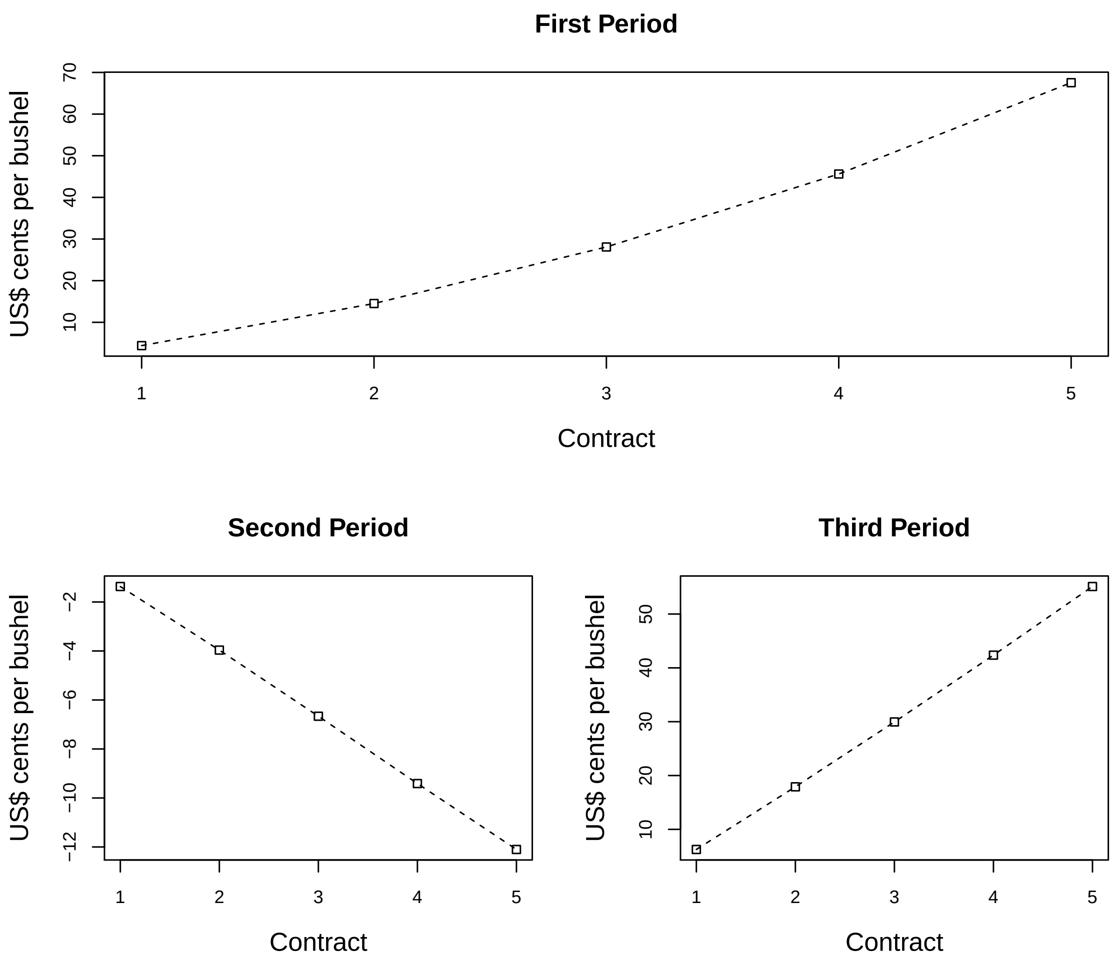
Source: Prepared by the author (2017)

Table 3 also shows that, in the second period, the model implied risk premiums are negative and lower, in absolute terms, than in the first period. This means that future prices are now higher than the expected future spot price. As seen in section 2, that is the case where consumers hedge their positions, going long in the future contract to guarantee lower prices in the future. Therefore, they pay the required premium for speculators as they go short, because they need prices greater than the ones in spot market. It is important to note that the standard deviation computed in the entire second period is significantly lower than in the first and third periods.

Finally, it can be seen, that in the third period the implied risk premium is positive. Again, this is typically the case of the first period, which is in normal backwardation. Furthermore, the mean and the standard deviation in the third period have the approximately the same magnitude as those in the first period.

Figure 4 presents the mean of the model-implied risk premium for each contract. The top presents the first period, and the bottom shows the second and third periods, wich have opposite signs.

Figure 4 – Implied risk premium (mean values) for each contract in all periods



Source: Prepared by the author (2017)

To give more insight into the magnitude of the implied risk premium, Table 4 presents the mean of the ratio between the risk premium RP_{t,T_j} to the estimated spot price S_t (risk premium as percentage of the estimated spot price). Note again that the first and third periods have approximately similar magnitudes and that in the second period this ratio is much lower.

Table 4 – Ratio between the average risk premium and spot price

	F_1	F_2	F_3	F_4	F_5
First period	0.0064	0.0211	0.0409	0.0664	0.0984
Second period	-0.001	-0.0035	-0.0058	-0.0082	-0.0106
Third period	0.0051	0.0147	0.0246	0.0349	0.0455

Source: Prepared by the author (2017)

To sum up, in the first period, when soybean prices were soaring the prevalent hedgers were producers, who tried to lock in high prices. The opposite situation prevailed in the second period, when prices decreased abruptly. Consumers started to prevail, trying to guarantee low prices. In the third period, producers again prevail, since prices increased most of the time.

The final behavior of prices ahead of 2014 is decreasing. Since the data are sparse, probably the ICSS algorithm was not able to capture changes in variance/volatility. Perhaps the continuation of this price regime will bring some evidence of a new change in variance/volatility and hence in the risk premium. To our knowledge there is not any empirical study on soybean risk premium covering this period. This lack of information prevents us from comparing our findings with empirical research.

5 Conclusion

We analyzed the risk premium in soybean futures prices using a well-known two-factor model in the commodity literature. First we evaluated changes in risk premium following changes in volatility according to the ICSS algorithm. Next calibrated the model for each one of the three periods that were mapped. In the first and the third periods (when prices were rising most of the time) hedging positions of producers prevailed and the risk premium was found to be positive.

In the second period (when prices decreased) consumers hedged and the risk premium was negative. In all cases the absolute value of the risk premium increased with maturity of the contract. Despite the plunge in prices at the end of the period studied, we did not capture evidence of changes in variance/volatility. Probably this is because of scarcity of data.

We suspect that the continuation of this regime of prices will bring another change in agents' risk perception. Summarizing: (i) following the structural breaks in variance, the methodology was able to map changes in risk premium; (ii) we found evidence from this study that the implied risk premium changed not only in sign but also in magnitude, so risk premium is time-varying in the data sampled.

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